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per cent of aluminum. According to Langworthy and Austen human milk also contains small quantities of aluminum. Thus it is evident that the aluminum had to be absorbed from the gastrointestinal canal in order to be secreted with the milk.

Toxic symptoms have been described by various investigators who have studied the effect of the soluble aluminum salts on animal bodies. To determine whether the quantities found in human food have any deleterious effects on man will necessitate considerable further research. The chemical constitution of the aluminum compounds contained in these vegetable products is under investigation.

In conclusion, it may be said that aluminum is present in certain foods in rather large quantities in a water-soluble form, and that the daily consumption of aluminum on a mainly vegetable diet may assume large proportions.

We are indebted to Mr. Hartley, of the Bureau of Plant Industry, for many of the samples of corn used in this investigation. Some of the foreign corn was obtained through the courtesy of Dr. C. H. Lavinder, of the United States Public Health Service.

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## PLAGUE IN HAWAII.

### WITH SPECIAL REFERENCE TO ITS OCCURRENCE ON THE NORTHERN COAST OF THE ISLAND OF HAWAII.

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In December, 1899, the first cases of plague known to have occurred in the Hawaiian Islands appeared in the Chinese quarter of Honolulu on the island of Oahu. The disease subsequently developed on the other important islands of the group. The first case to be recognized on Hawaii, the largest island, occurred early in February, 1900. The type of the disease wherever it appeared was bubonic, though a few cases of what was regarded as primary pneumonic plague occurred. Rat infection undoubtedly existed as the primary cause of the disease in all of the outbreaks, but there was no systematic rodent examination or rodent extermination in the earlier years, this being prior to the recognition of the rat as the essential agent in the spread of the bubonic type of plague. The disease was suppressed in each locality in which it appeared with the exception of the northern coast of Hawaii and in the city of Honolulu. Cases occurred from time to time in Honolulu up to July 14, 1910.

From Hilo, the chief city of the island of Hawaii, where the disease appeared in 1900, the infection spread along the line of commercial

intercourse toward the south, cases appearing in several villages and plantation camps. The usual antiplague measures sufficed to limit and extinguish the infection, though it reappeared in several villages.

With the exception of the outbreak that occurred on the northern coast of Hawaii, the disease throughout the islands presented the usual characteristics of plague, and epidemiologically there were no points of particular importance. In the excepted locality there were certain features of special interest that will be considered in this paper.

#### Plague on the Northern (Hamakua) Coast of Hawaii.

(a) *Local conditions.*—The coast line of the island of Hawaii runs in a general direction north and northeast from Hilo, the principal city. With few exceptions the shore line is characterized by precipitous cliffs from 20 to 100 feet or more in height. There are no harbors, and steamers lie offshore, discharging cargoes and loading raw sugar, the only export, by means of a cable and sling, or basket. This fact is mentioned, as it is certain that there is much less danger of rats passing between a vessel and the shore under these conditions than in places where a vessel lies at a dock, or even where cargo is transferred in lighters. The district under consideration is approximately 60 miles long. The forest line runs roughly parallel with the shore and from three to five miles distant from it. The intervening space is entirely occupied by sugar plantations and nearly all of the land is planted in cane. The northwestern extremity of the district is marked by a deep valley (Waipio) beyond which there is practically no traffic. Until comparatively recently, when a railroad was completed, all of the local commerce has been carried on in stages and wagons.

The climatic conditions are similar to those of the windward coasts of the other islands of the group. During the winter months the temperature may fall as low as 55°, while in summer it is exceptional to have it rise above 85°. The rainfall varies considerably, but it averages about 90 inches per year. The population of the district is approximately 9,000, among which 19 cases of plague have occurred in a period of four years.

There are two important villages in the district, Honokaa, with a population of about 300, and Kukuihaele with about 100. Six cases of plague have occurred in the former and four in the latter, while nine were scattered among the plantations.

(b) *Human plague.*—A list of all cases that have occurred, with certain data in connection therewith, is shown here.

TABLE 1.—*Human plague cases—Hamakua district.*

| Case No. | Date.    | Type.      | Location of bubo. | Sex.      | Age. | Nationality.         | Occupation.                 |
|----------|----------|------------|-------------------|-----------|------|----------------------|-----------------------------|
|          | 1910.    |            |                   |           |      |                      |                             |
| 1        | Mar. 13  | Bubonic... | Cervical...       | Female... | 13   | Scotch.....          | Schoolgirl.                 |
| 2        | ..do.... | ..do....   | ..do....          | ..do....  | 5    | ..do....             | Do.                         |
| 3        | Dec. 16  | ..do....   | ..do....          | Male....  | 25   | Filipino....         | Cook.                       |
|          | 1911.    |            |                   |           |      |                      |                             |
| 4        | Jan. 23  | ..do....   | ..do....          | Female..  | 2    | Hawaiian....         | Child.                      |
| 5        | ..do.... | Pneumonic  | ..do....          | Male....  | 2    | Chinese-Hawaiian..   | Do.                         |
| 6        | Apr. 19  | Bubonic... | Cervical...       | ..do....  | 21   | Hawaiian....         | Mill hand.                  |
| 7        | Oct. 22  | ..do....   | ..do....          | ..do....  | 12   | ..do....             | Schoolboy.                  |
| 8        | Oct. 27  | ..do....   | ..do....          | ..do....  | 69   | ..do....             | Policeman.                  |
|          | 1912.    |            |                   |           |      |                      |                             |
| 9        | Feb. 8   | ..do....   | ..do....          | ..do....  | 16   | Portuguese-German... | Garbage - w a g o n driver. |
| 10       | Feb. 25  | ..do....   | Axillary...       | ..do....  | 32   | Japanese.....        | Mill hand.                  |
| 11       | ..do.... | ..do....   | Cervical...       | Female..  | 40   | ..do....             | Housewife.                  |
| 12       | Mar. 14  | ..do....   | ..do....          | Male....  | 12   | Portuguese-German... | Schoolboy.                  |
| 13       | Dec. 14  | Pneumonic  | ..do....          | Female..  | 6    | Japanese.....        | Schoolgirl.                 |
| 14       | Dec. 15  | Bubonic... | Inguinal..        | Male....  | 9    | Hawaiian....         | Schoolboy.                  |
| 15       | ..do.... | ..do....   | ..do....          | ..do....  | 65   | ..do....             | Teamster.                   |
|          | 1913.    |            |                   |           |      |                      |                             |
| 16       | Jan. 11  | ..do....   | ..do....          | Female..  | 7    | Filipino.....        | Schoolgirl.                 |
| 17       | Jan. 30  | ..do....   | ..do....          | Male....  | 48   | Hawaiian....         | Poi manufacturer.           |
| 18       | May 1    | Pneumonic  | ..do....          | Female..  | 37   | English.....         | Housekeeper.                |
| 19       | May 8    | ..do....   | ..do....          | ..do....  | 35   | ..do....             | School-teacher.             |

The first case (No. 1) recognized as plague that occurred in this district developed in the village of Honokaa on March 8, 1910, the victim being the 13-year-old daughter of a well-to-do merchant. A second child (No. 2) a girl aged 5, in the same family, sickened two days later. Both cases were fatal; indeed, every case that has occurred has succumbed, death occurring in from 36 hours to 5 days after the onset of the symptoms.

Cases 4 and 5 occurred on the same day, though the patients lived 2 miles apart. In each of these cases, however, the father was employed in a sugar mill from which an infected rat was taken a few days after the death of the children.

Case 7, a boy, and case 8, an old man, lived in the same house. It was not possible to satisfactorily account for the origin of the infection in either of these. The man, a policeman, frequented a locality where a plague rat had been taken a month before; possibly he carried the disease home in the shape of infected fleas, an occurrence that, according to some writers is believed to be common.

Cases 10 and 11 occurred on the same day though they lived about 8 miles apart. Infected rats were found near where each of the persons worked or lived at about the same time that the illness began.

Cases 13, 14, and 15 occurred at practically the same time and all lived in the same neighborhood. An infected rat was found a few days later under the house where No. 13 had lived.

An infected rat was found near the house in which case 18 (May 1) lived. Case 19 (May 8) nursed case 18 and may have been infected

from the former—both were of the pneumonic type—or the infection may have come from the same external source.

Cases 9 and 12 were of much interest. They were brothers, and lived in the same house. The first probably contracted the disease at a stable where an infected rat had been found about a week prior to the beginning of the boy's illness. After his death the house was disinfected with bichloride of mercury, but it was not fumigated, as the infection was believed to have been acquired elsewhere; nevertheless, 34 days later the younger brother was taken sick. Both of us happened to be on the ground when the second boy became ill. Every effort to trace the infection was without avail. An infected rat had been found in the village about two weeks before the boy became sick, but there was no clear association of the boy with the infected premises. After the boy died the house was fumigated twice with sulphur dioxide and once with hydrocyanic acid, roaches and other bugs being killed by each fumigation.

A careful search failed to reveal any dead rats in the house or in the vicinity either before or after the fumigation, and a careful watch was kept while the fumigation was in progress for the purpose of killing any rat that might try to escape, but none was seen. There were no rat holes under the house, though there were some in the floor, which was above the ground from 4 inches to 3 feet, the house standing on sloping ground. Flour bags in the kitchen had been cut by rats or mice and droppings had been seen. The members of the family declared that they had not been aware of the presence of rats for several months, but that prior to this period of freedom the house was infested. Only one rat had been caught on the premises between the death of the older brother and the sickening of the younger one, and that was taken at a stable about 50 yards from the house. It was negative for plague. The house had a double roof, an old one of shingles having been covered by one of corrugated iron. The latter was removed and one rat's nest, apparently long deserted, was found. We might mention here the fallacy of paying any attention to the finding of dead rats in tracing infection, unless they are found to have plague, as a dead *Mus rattus* was found in the yard in front of the house a couple of days after the death of the second boy, and a dead *Mus norvegicus* was found at the barn where he had played. Neither rat was plague infected.

In examining the table one is impressed by the large proportion of cases showing cervical buboes. Thus of the 19 cases, 15 were of the bubonic type and of these, 10 (66.6 per cent) had the bubo in the neck. Among 43 cases of the bubonic type of plague occurring in other parts of the island but one presented a cervical bubo. We have no explanation for this unduly large percentage of cases in which the neck glands were affected. So far as we have been able to determine, the

conditions under which the people live, the rodents that infest the region, and the parasites found on man and on rodents, do not differ from those in other parts of the island. We collected a number of parasites, head lice, and bedbugs from one of the cases with neck buboes. The bedbugs were shown by the guinea-pig test to harbor *Bacillus pestis*, while the head lice were negative. One would expect to find the bacillus in bedbugs taken from any plague patient in which septicemia was present; this, of course, would include a very large proportion of cases.

Attention is called to the fact that none of the cases has occurred during the months of June, July, August, and September, while 14 of the 19 occurred in the months of December, January, February, and March.

(c) *Rodents and rodent infection*.—The total number of rodents, taken in connection with the antiplague campaign, is shown in the following table:

TABLE 2.—*Number and species of rodents taken.*

| Species.                      | Number taken. | Percentage of all taken. | Percentage of rats and mice taken. |
|-------------------------------|---------------|--------------------------|------------------------------------|
| <i>Mus norvegicus</i> .....   | 22,996        | 15.66                    | 15.99                              |
| <i>Mus alexandrinus</i> ..... | 20,721        | 14.08                    | 14.41                              |
| <i>Mus rattus</i> .....       | 25,422        | 17.28                    | 17.68                              |
| <i>Mus musculus</i> .....     | 74,678        | 50.77                    | 51.92                              |
| Mongoose.....                 | 3,271         | 2.22                     | .....                              |
| Total.....                    | 147,088       | .....                    | .....                              |

Rats do not appear to be particularly numerous in the region under consideration. If the accounts of old residents are reliable these rodents were so prevalent some years ago as to interfere materially with the growing of sugar cane. The mongoose was introduced for the purpose of reducing the number of rats and it is believed that some success has attended the experiment.<sup>1</sup>

*Habitat*.—Most of the rats came from stables and about residences either in the villages or on the plantations (camps).

The village of Honokaa (population 300), the largest community in the section, did not appear to be badly infested, as 200 traps yielded but about 5 rats per day. This relative scarcity of rats was probably due to the fact that when the first cases of plague appeared in 1910 the village had been pretty generally "rat proofed" by tearing out floors that rested on the ground and by elevating buildings so that the natural enemies of the rat might move about freely underneath.

<sup>1</sup> There is some doubt on this point as rats are said to have been much reduced on Kauai, one of the Hawaiian islands, on which mongoose have never been permitted.

In the country districts rats are frequently caught in the cane fields, but it is believed that they generally make their nests in stone piles, gulches, stone fences, etc. The question arose as to whether it would be advisable to attempt to abolish the breeding places in stone fences and stone piles, but it was decided that even if extermination on such a large scale proved practicable it was quite possible that if the natural breeding places were interfered with the rodents might seek new quarters in and about human habitations where they would become a more serious menace than in their natural haunts.

*Parasites*.—The conditions were not favorable for collecting and examining fleas, as the rodents were all brought to the laboratory together in one container. The following is the result of the few identifications that were made:

*Loemopsylla cheopis*, 9; *Ctenocephalus felis*, 9; *Ctenocephalus canis*, 4.

The only point of interest is the presence of *L. cheopis*, the rat flea of tropical countries, which has been shown to be the usual plague carrier in India and doubtless is in other warm countries.

TABLE 3.—Distribution of rat infection, by years.

| Year.      | Norvegicus. | Rattus. | Musculus. | Mongoose. | Species not stated. | Total found infected. |
|------------|-------------|---------|-----------|-----------|---------------------|-----------------------|
| 1910.....  | 3           | 0       | 1         | 0         | 4                   | 8                     |
| 1911.....  | 3           | 0       | 0         | 0         | 0                   | 3                     |
| 1912.....  | 20          | 21      | 30        | 1         | 6                   | 78                    |
| 1913.....  | 4           | 2       | 1         | 0         | 6                   | 13                    |
| Total..... | 30          | 23      | 32        | 1         | 16                  | 102                   |

TABLE 4.—Proportion of plague among the several species.

| Species.                      | Examined. | Found infected. | Proportion infected. |
|-------------------------------|-----------|-----------------|----------------------|
| <i>Mus norvegicus</i> .....   | 22,996    | 30              | 1:766                |
| <i>Mus rattus</i> .....       | 25,422    | 23              | 1:1106               |
| <i>Mus musculus</i> .....     | 74,678    | 32              | 1:2334               |
| Mongoose.....                 | 3,271     | 1               | 1:3271               |
| <i>Mus alexandrinus</i> ..... | 20,721    | 0               | .....                |
| Not identified.....           | .....     | 16              | .....                |
| Total.....                    | 147,088   | 102             | 1:1442               |

The figures in the tables are taken from the laboratory records. We suspect that errors of identification make these figures somewhat untrustworthy, especially on account of the apparent absence of infection among *M. alexandrinus*.

More trustworthy we believe is the following tabulation, showing places from which infected rodents were taken.

TABLE 5.—*Nature of places where infected rats were found.*

| Place.              | Norvegicus. | Rattus. | Musculus. | Mongoose. | Not identified. | Total. |
|---------------------|-------------|---------|-----------|-----------|-----------------|--------|
| House.....          | 17          | 5       | 6         | 0         | 8               | 36     |
| Camp.....           | 5           | 2       | 12        | 1         | 0               | 20     |
| Railroad track..... | 0           | 0       | 1         | 0         | 0               | 1      |
| Gulch.....          | 3           | 1       | 1         | 0         | 0               | 5      |
| Stable.....         | 4           | 2       | 6         | 0         | 8               | 20     |
| Churchyard.....     | 0           | 0       | 1         | 0         | 0               | 1      |
| Cane field.....     | 1           | 10      | 4         | 0         | 0               | 15     |
| Cargo landing.....  | 0           | 2       | 0         | 0         | 0               | 2      |
| Stone wall.....     | 0           | 1       | 1         | 0         | 0               | 2      |
| Total.....          | 30          | 23      | 32        | 1         | 16              | 102    |

In the early part of the work the microscopical examination of the spleen was depended upon in picking out suspected rodents which were then submitted to cultural and inoculation tests. Later, after the laboratory force had had the opportunity of becoming familiar with the gross lesions of rat plague, the naked eye was depended upon for detecting rats that required more detailed study. The results of this latter method fully justified the high esteem in which it is held by those who have had experience with it.

*Infection in the mongoose.*—A single case of plague in the mongoose came under observation during the work. The case was detected by Dr. F. W. Taylor, of Pauillo, Hawaii, who supervised the dissection of rodents in the infected district. A careful study of the culture secured from the animal showed that it did not differ in any respect from cultures obtained from rats and from man. We are acquainted with the fact that the mongoose has been shown to be susceptible to laboratory infection with the plague bacillus but we do not consider this rodent a factor of importance in the spread of the disease in Hawaii. Our reasons for holding this view are as follows:

(1) But a single infected mongoose was found among several thousand examined.

(2) These rodents do not appear to harbor ecto-parasites. We have examined a great many of them but we have found no ecto-parasites that did not clearly come from other rodents.

(3) These rodents do not generally come into close association with man.

Until recently the rats were examined at a branch laboratory maintained in the field at Honokaa but since railroad communication has been established they are shipped from each collecting station to the central laboratory at Hilo. A sealed glass container, which is incased in a wooden box, is employed, a packing of felt obviating the danger of breakage.

The antiplague measures that have been taken are the trapping and poisoning of rodents, the establishment of a garbage collection

service in the villages and on the plantations throughout the district, the removal of nearly all of the wooden floors that rested on the ground and replacing them by concrete, or elevating the floor so that there would be no opportunity for rats to harbor underneath, and the removal of double partitions wherever they have been found. These measures have, however, been less effective than they would have been in a locality where the rodent population was not so largely made up of *Mus rattus* and *Mus alexandrinus*. We are not acquainted with any very satisfactory mode of dealing with these species of rats.

The problem of rodent plague in this district is in many respects similar to that presented by the ground squirrel infection in California. It is essentially a problem of the destruction of rural rodents, in this case, rats and mice. There is this difference, however: The ground squirrel is readily killed by poisoned grain and poisonous gases, while rats are far more difficult to destroy.

After a careful study of the situation we have come to the conclusion that the only practicable measures are those directed toward keeping the environments of villages and camps as free from rats as possible, as an attempt at general extermination would be prohibitively expensive.

We wish to acknowledge our indebtedness to Dr. J. S. B. Pratt, president of the territorial board of health, for access to much of the data employed in the preparation of this paper.

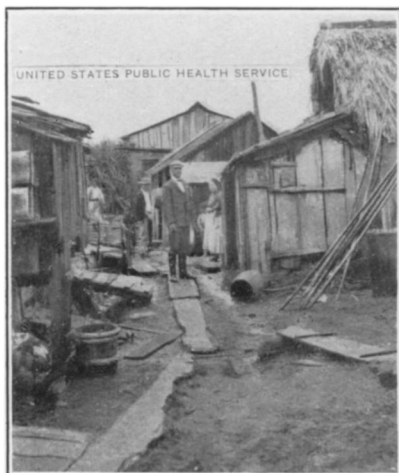


FIG. 1.—A RAT-INFESTED CORNER OF CAMP



FIG. 2.—RAT-PROOFING LUMBER BY ELEVATION ON CONCRETE PILLARS



FIG. 3.—BUILDINGS OF CAMP ELEVATED AS RAT PROOFING MEASURE.